Reducing Uncertainty in Reasonable Assurance Analysis (RAA) through an Enhanced BMP Effectiveness Dataset

Background

- In 2017-18, STORMS held two workshops to develop guidance for Alternative Compliance
- A major outcome was how to address uncertainty within Reasonable Assurance Analysis (RAA)
- STORMS selected a follow-up project to address RAA uncertainty: BMP performance

Project Goals

- Largest resource for BMP performance data is currently the International BMP Database
- Uncertainty arises because most of the IBMPDB is not from California
  - Nearly all of the California data is >10 years old
- Goal of this project is to compile updated performance data specifically for California

Approach

- Select the BMPs and pollutants we want
- Outreach to data generators
  - Compile as much data as possible
- How well does each BMP perform by pollutant?
  - How do we measure performance?
  - Can we figure out why some perform better than others?

Focus on Flow-Thru BMPs

- Media filters
- Dry pond
- Wet pond
- Constructed wetland
- Vegetated swale
- Bioretention with underdrain
- Permeable pavement

Focus on Representative Pollutants

- Flow
- Bacteria
  - *E.coli*
  - *Enterococcus*
- Trace metals
  - Copper (total and dissolved)
  - Lead (total and dissolved)
  - Zinc (total and dissolved)
  - Mercury (total)
- Nutrients
  - Nitrate
  - Phosphorus
- PCBs

Queried 45 Different Data Generators

- Municipalities
- Consultants
- Non-profits
- Caltrans
- Stormwater Associations
- Sewer Districts
- Water Agencies

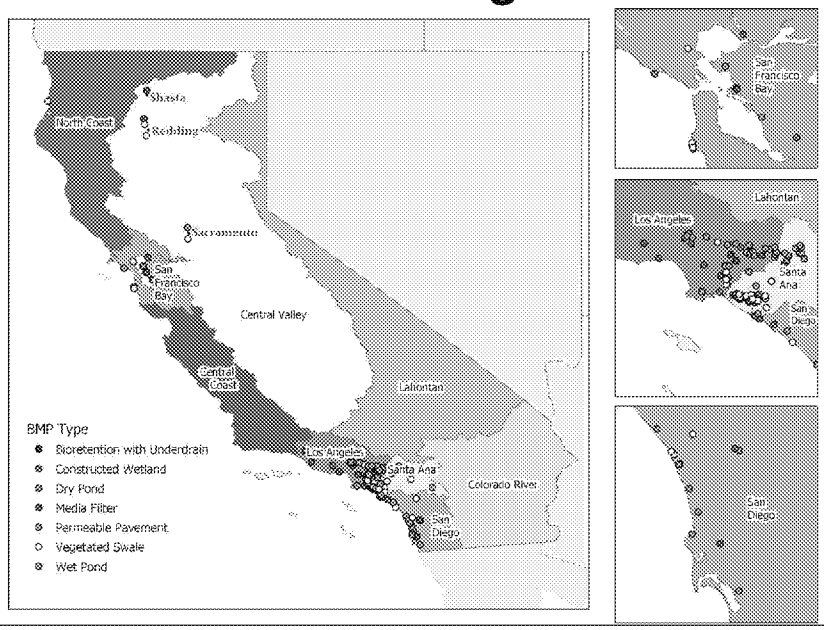
Road Map to Results

- Inventory of compiled data
- Evaluating how best to assess performance
- Performance comparison among BMPs
- Changes in performance with climate or geography

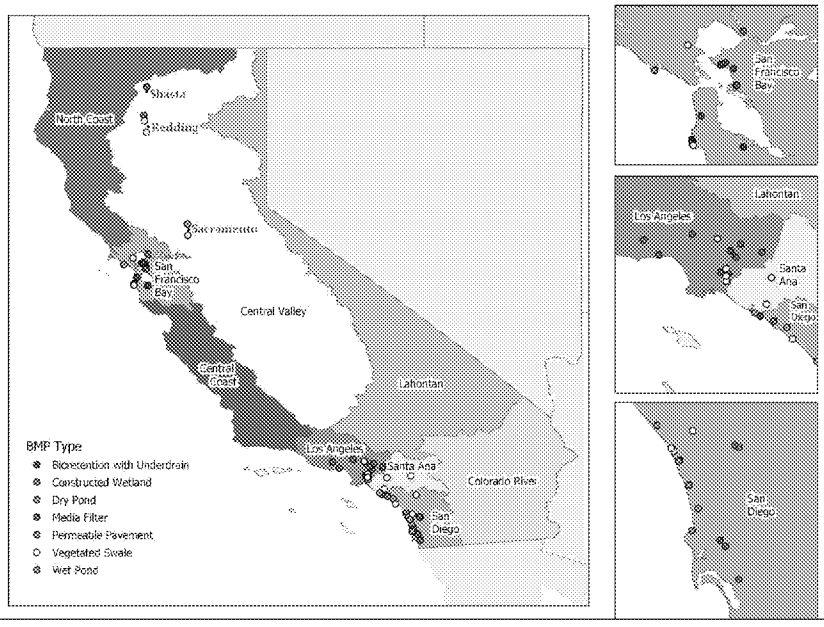
Inventory of Compiled BMP Data

BMP Category	Number of BMPs with Data				Number of Site-Storm Events
	Background Info	Design Specs	Flow Data	Water Quality Data	
Vegetated Swale	45	22	24	27	380
Media Filter	65	19	16	28	366
Dry Pond	7	6	8	6	99
Wet Pond	48	3	5	5	125
Constructed Wetland	5	1	1	2	657
Permeable Pavement	22	6	0	2	2
Bioretention System with Underdrain	23	12	3	13	71
Total	**214**	**69**	**57**	**81**	**1700**

Statewide BMPs with Background Information



Statewide BMPs with Water Quality Monitoring Data



Regional Distribution of BMPs with Monitoring Data

BMP Type	San Francisco Bay R2	Los Angeles R4	Santa Ana R8	San Diego R9	Central Valley R5
Bioretention with Underdrain	10			3	
Constructed Wetland				1	
Dry Pond		2		4	
Media Filter	11	10		5	2
Permeable Pavement	1			1	
Vegetated Swale	8	6	5	5	3
Wet Pond	2	1			1
TOTAL	**32**	**19**	**5**	**19**	**6**

Sample Size for BMP-Pollutant Pairs

BMP Type	Dry Pond	Media Filter	Vegetated Swale	Wet Pond
Flow	91	166	283	32
Cu	68	192	277	60
Pb	69	199	277	59
Zn	68	197	276	60
Hg	0	3	5	12
Nitrate	68	186	262	45
TKN	68	159	258	58
Total Phosphorus	67	183	257	58
PCB	0	3	0	0

Temporal Distribution of WQ Monitoring Data

BMP Type	Pre-2000	2000-05	2006-10	2011-15	2016-20	Total Data Pairs
Bioretention with Underdrain	0	0	0	0	51	51
Constructed Wetland	289	889	874	685	0	2737
Dry Pond	100	644	0	0	0	744
Media Filter	111	1312	234	267	43	1967
Permeable Pavement	0	0	0	1	0	1
Vegetated Swale	0	1826	787	65	35	2713
Wet Pond	193	136	117	6	40	492
TOTAL	**693**	**4807**	**2012**	**1024**	**169**	**8705**

Summary of Inventory

- Double the number of BMPs and storm events in the IBMPDB
- 4 out of 7 BMPs with sufficient data
- 8 out of 14 pollutants with sufficient data
- Half the data is now < 10 years old
- About evenly split between Bay area and So Cal

Road Map to Results

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Four Methods To Estimate "Performance"

- Percent reduction
  - Influent concentration – Effluent concentration
- Effluent probability
  - Probability distribution
- General linear regression
  - Relationship between influent and effluent
- Quantile regression
  - Relationship between influent and effluent

As an example:

Dissolved Cu removal in Vegetated Swale

✓ 8 Years of data
✓ 23 BMPs
✓ 258 storm events

Percent Reduction

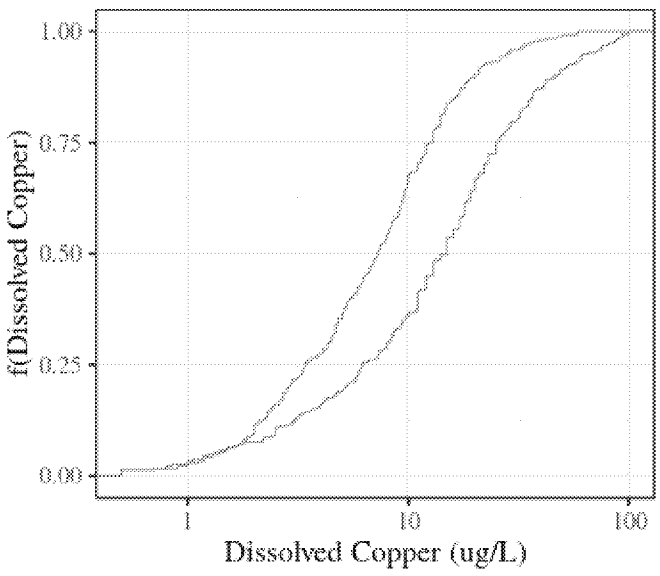
BMP Efficiency (%) = $\frac{C_{in}-C_{eff}}{C_{in}}$x100

Vegetated Swale: **17 ± 52 %** removal of Dissolved Copper Concentration

- The most common approach
- Requires paired influent and effluent data
- Performance typically calculated as the average
- Can become biased when concentrations get very low

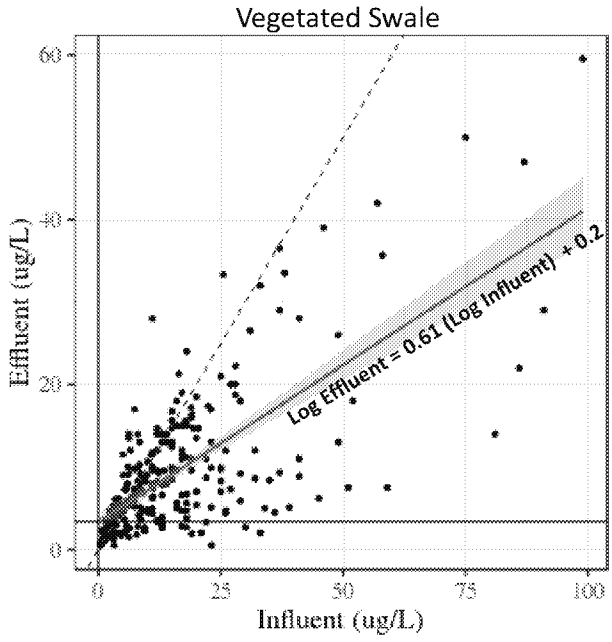
Effluent Probability Method

- Good for assessing distribution of expected effluent concentrations
- Does not require paired Influent-Effluent data
- We calculated removal by picking the 50% influent concentration and subtracting the effluent concentration



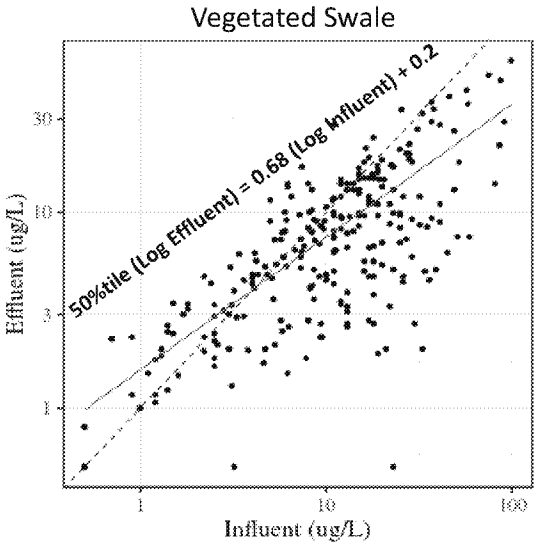
Linear Regression

- Focuses on the influent-effluent relationship
- Uses typical regression statistics
  - Assumptions about normality
- Provides an estimate of the average
- We estimated removal by applying the median influent concentration

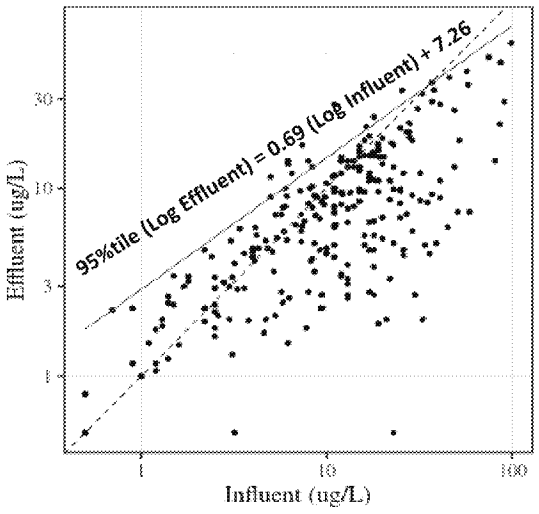


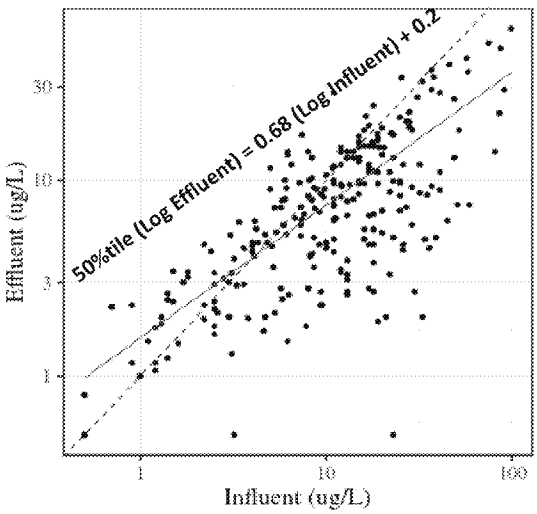
Quantile Regression

- Focuses on the influent-effluent relationship
- Uses "novel" regression statistics
  - No assumptions about normality
- Provides an estimate of any portion of the distribution
- We estimated removal by applying the median influent concentration

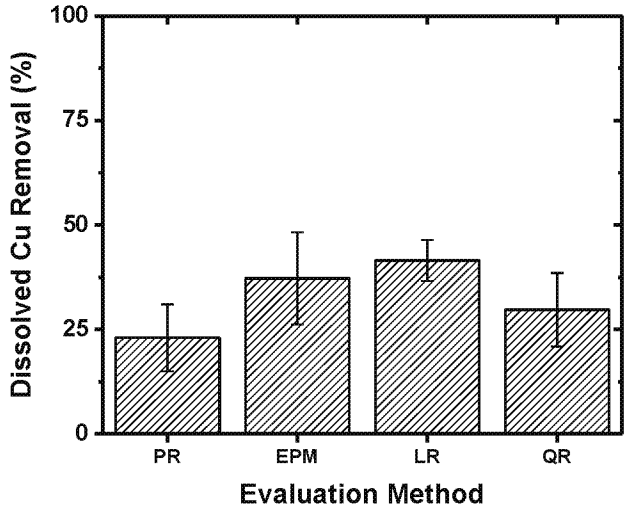


Quantile Regression

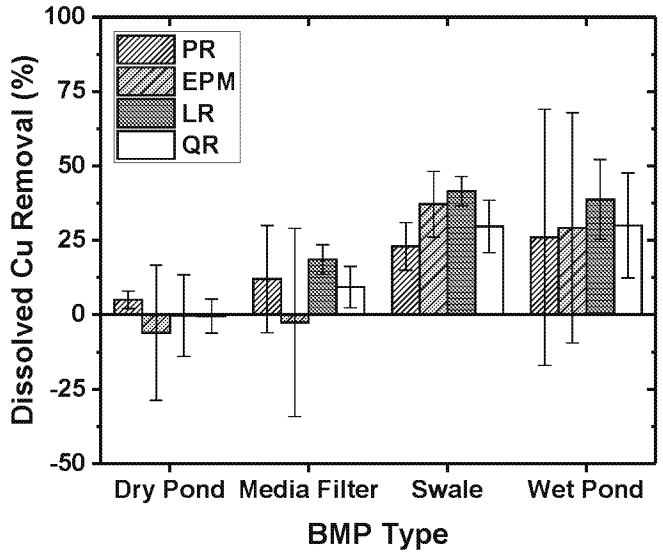




How Effective are Vegetated Swales at Removing Dissolved Copper from Stormwater?



Evaluation Method Can Alter Your Perception



Pros and Cons for Evaluation Method

	Percent Reduction	Effluent Probability	Linear Regression	Quantile Regression*
Provides an estimate of the average	X	X	X	X
Provides relationship between influent and effluent			X	X
Unbiased with outliers or non-normal data		X		X
Provides estimate of the distribution (uncertainty)		X		X

* Remainder of presentation will focus on Quantile Regression

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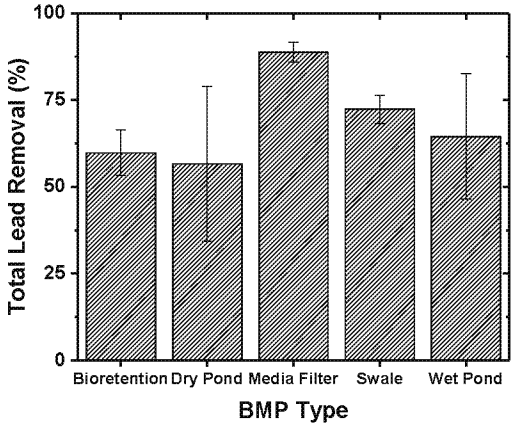
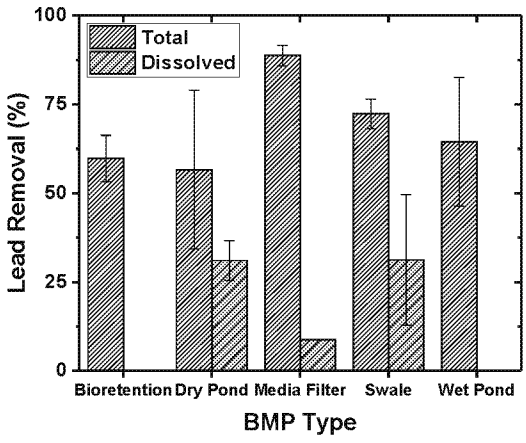
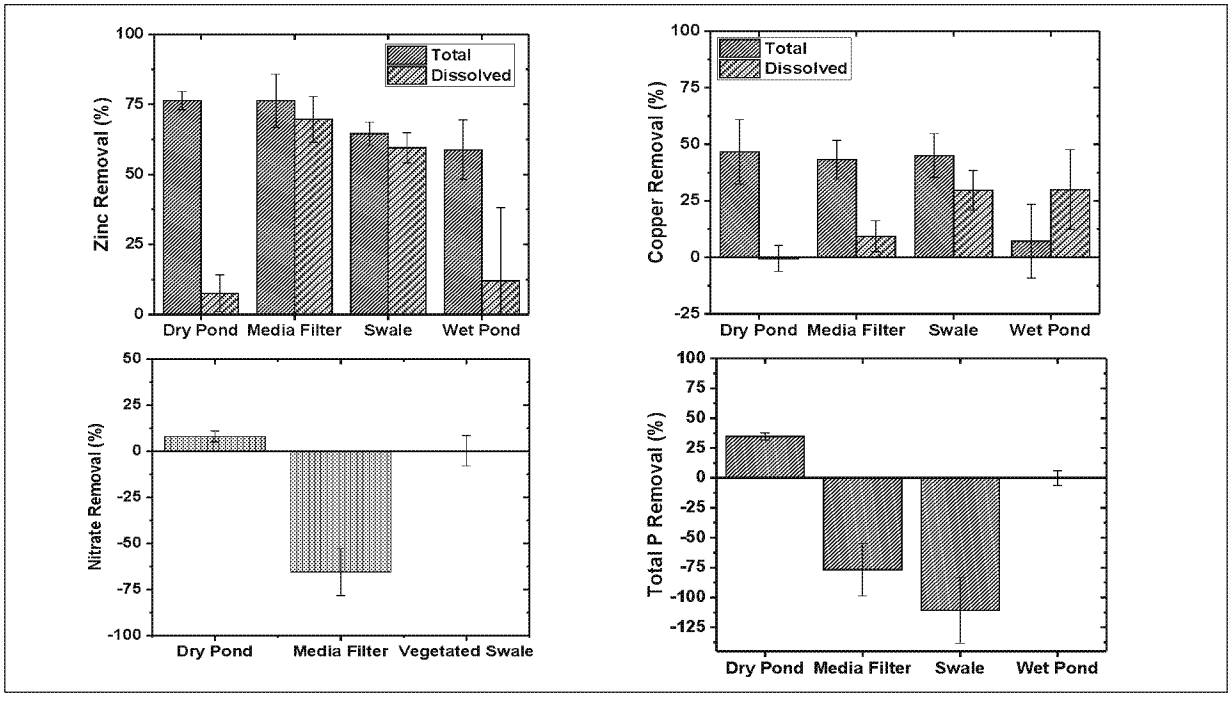
Which is the Best BMP for Removing Lead?



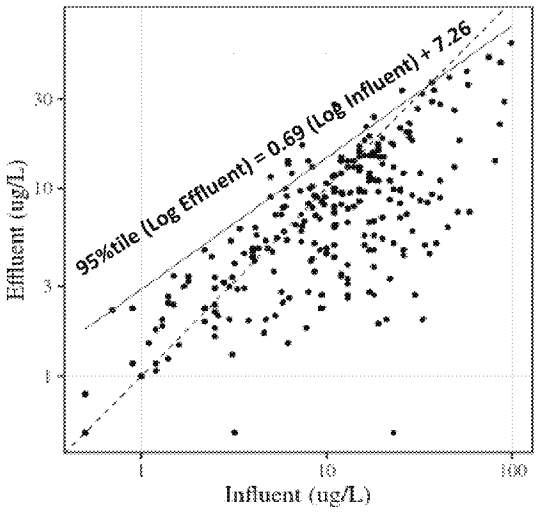


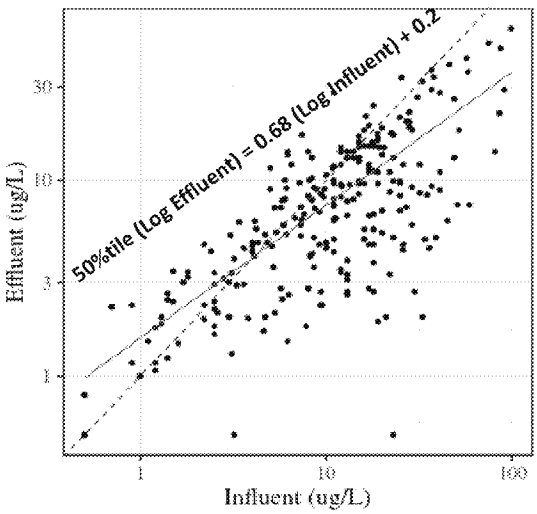

Zinc Removal (%)
Total
Dissolved
Dry Pond
Media Filter
Swale
Wet Pond
Copper Removal (%)
Nitrate Removal (%)
Vegetated Swale
Total P Removal (%)

What About Uncertainty?

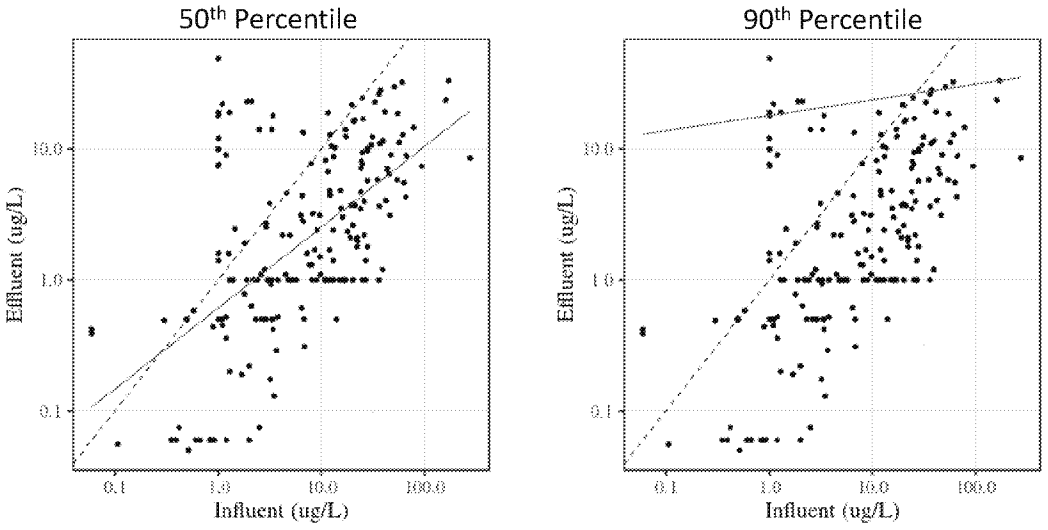
- So far, I've been showing you standard deviation about the mean/median
- That may not be the best choice if you want to capture the range of uncertainty
  - Improve your probability of reaching treatment goals
- Quantile regression allows you to estimate different probabilities of success

Quantile Regression

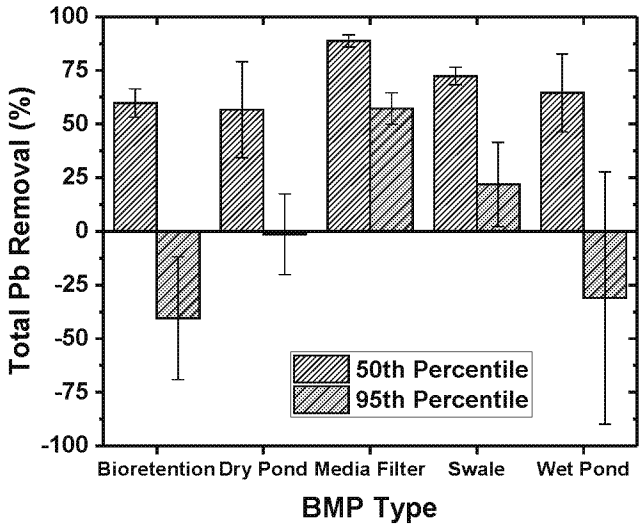




Total Lead Removal in Media Filters



Confidence vs Efficiency



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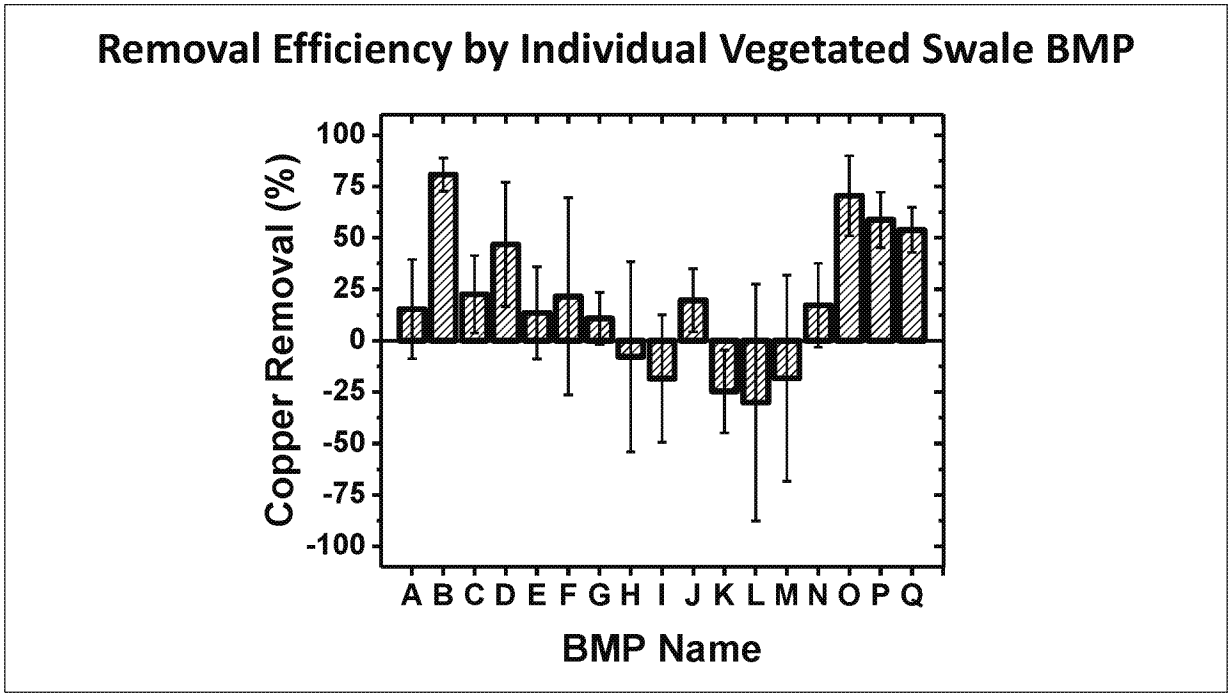
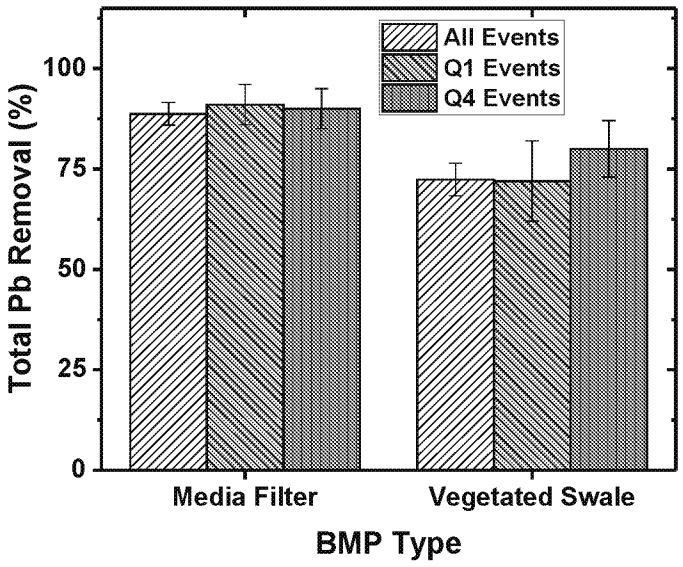
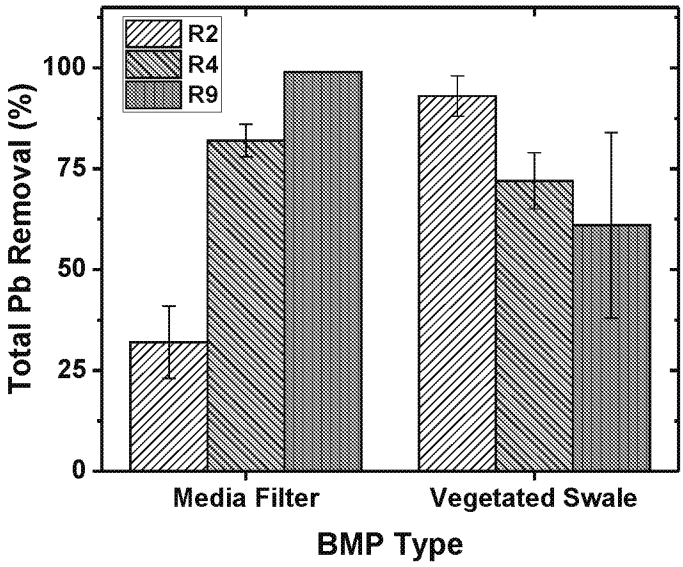

Removal Efficiency by Individual Vegetated Swale BMP
Copper Removal (%)
100
75
50
25
0
-25
-50
-75
-100
A B C D E F G H I J K L M N O P Q
BMP Name

BMP Performance Among Differing Storm Sizes



BMP Performance Among Differing Regions

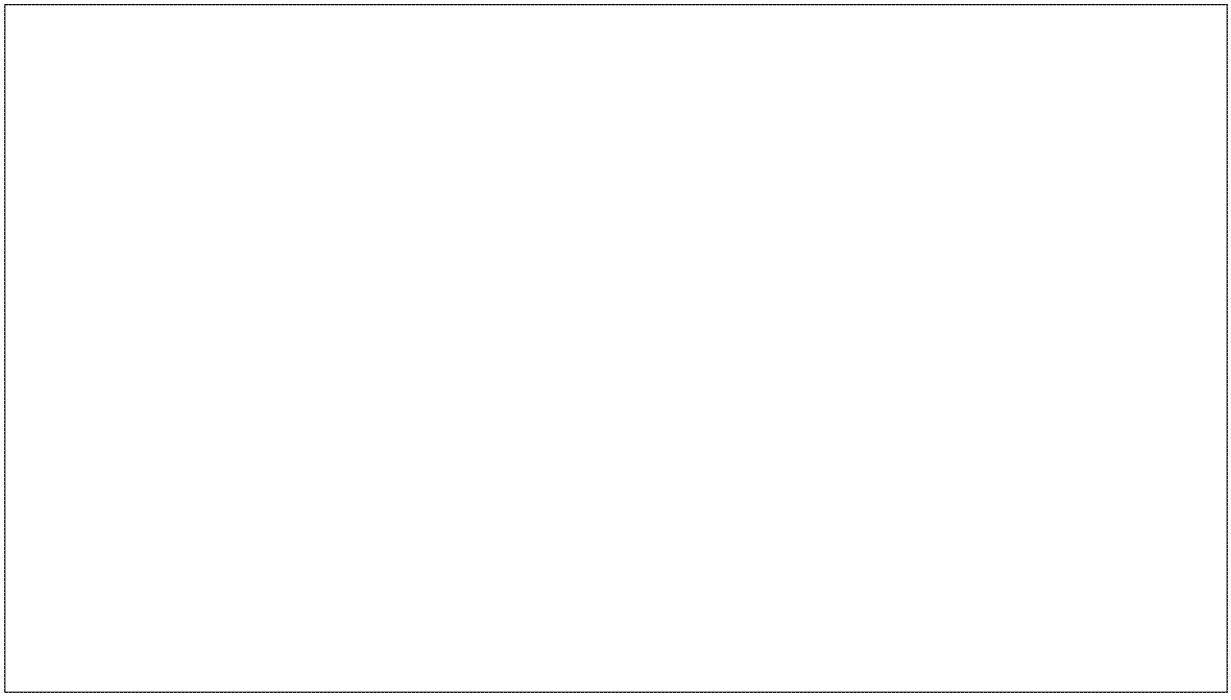


Our Next Steps

- Finish summarizing performance for all BMP-Pollutant pairs
- Complete our assessment of what could be causing the variability
- Final Technical Report by March 31
  - Journal article
- Decide where the data should “live”

Options for Public Facing Data Set

- SWRCB (i.e., OIMA)
- Individual RWQCBs
- International BMP database
- CASQA or SMC
- University
- SCCWRP or SFEI



Dominant land use for BMP locations with monitoring data

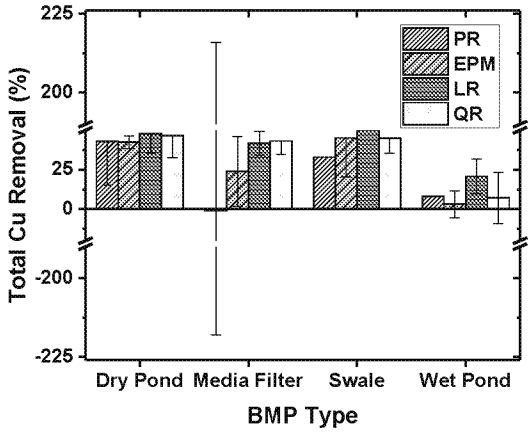
BMP Type	Residential	Industrial	Commercial and Services	Other Urban or built-up land	Rangeland, Pasture or open space	Transportation, communication, and services
Bioretention with Underdrain	5	5	3	x	x	x
Constructed Wetland	x	x	1	x	x	x
Dry Pond	2	x	2	1	1	x
Media Filter	12	x	9	2	4	1
Permeable Pavement	1	x	x	1	x	x
Vegetated Swale	8	X	4	1	8	7
Wet Pond	x	x	x	x	3	x
Total	**28**	**5**	**19**	**5**	**16**	**8**

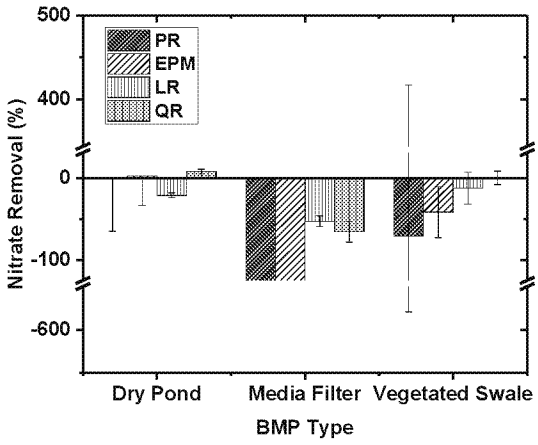
Not every BMP-Pollutant pair has same data coverage

❑ Analytes are only selected if 20+ data pairs from 5+ BMPs are available

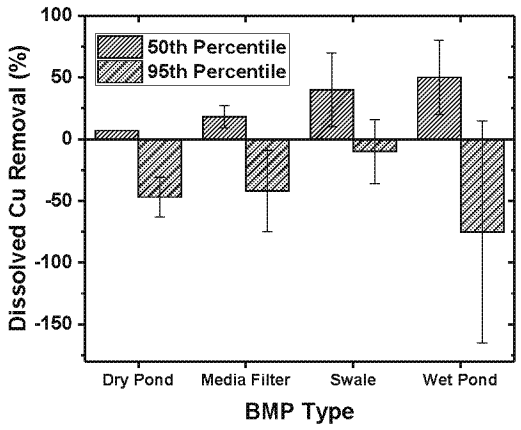
BMP Type	Analytes
Bioretention	Total Pb, Total Hg, Total PCB
Dry Pond	Pb, Cu, Zn, TKN, Nitrate, TP, Flow
Media Filter	Pb, Cu, Zn, TKN, Nitrate, TP, Flow
Vegetated Swale	Pb, Cu, Zn, TKN, Nitrate, TP, Flow
Wet Pond	Total Pb, Cu, Zn, TKN, Nitrate, TP, Flow

Comparing effectiveness evaluation methods for additional analytes





Percentile matters: Case of Dissolved Cu



Runoff Capture Effectiveness